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Health behaviors of American pregnant women: a cross-sectional analysis of NHANES 2007–2014

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ABSTRACT

Background This study examined engagement in five health behaviors among pregnant women in the USA.

Methods Pregnant women who participated in the National Health and Nutrition Examination Survey 2007–2014 were included in this study. Five health behaviors were examined: adequate fruit and vegetable consumption, prenatal multivitamin use, physical activity, sleep and smoking. Multivariable regressions were used to estimate the odds ratio and 95% confidence interval of characteristics associated with health behaviors.

Results Among 248 pregnant women, only 10.2% engaged in all five health behaviors and 35.4% consumed adequate fruits and vegetables. For adequate fruit and vegetable consumption, Hispanic and women of 'other' race were more likely to meet the recommendation compared to non-Hispanic white ($P = 0.01$ and $P = 0.03$, respectively); high school graduates were less likely to meet the recommendation compared to those with at least some college education or more ($P = 0.04$).

Conclusions Adequate fruit and vegetable consumption among pregnant women was poor and differed by race/ethnicity and education status. Because of the cross-sectional design, we cannot examine engagement in health behaviors continuously throughout pregnancy. Future research with longitudinal data over the course of pregnancy is needed to confirm these results.

Keywords fruit and vegetable consumption, health behavior, NHANES, pregnancy, race or ethnicity

Introduction

From a life-course perspective, the prenatal period has been recognized as a critical period for both women and their offspring.[1–3] A healthy intrauterine environment is a complex interplay between genetics, maternal behavior, environmental exposures and biopsychosocial responses that all have a synergistic effect on both mothers' and offsprings' health.[4] Findings from a wide body of research have improved our understanding of what exposures pregnant women should avoid, and behaviors they should engage in to support a healthy pregnancy.[5] To promote optimal health for pregnant women and their offspring, professional organizations have developed guidelines based on available scientific evidence.[6,7] Guidelines range from long-known recommendations, such as abstention from smoking[8] and taking nutrition supplements[9], to more recent evidence on the importance of adequate sleep[10,11] and nutrient intake from diet,[12] and engaging in physical activity.[13]

Maternal nutritional status during pregnancy is critical for both women and offspring's health.[14] Recent data have demonstrated that diets comprised of greater fruits and vegetables are associated with a lower risk of offspring who are born small-for-gestational-age.[15,16] Use of prenatal multivitamin supplements is recommended to ensure that women receive adequate concentrations of minerals and vitamins.[17] Physical activity and adequate sleep have been recognized as important health behaviors to protect against pregnancy complications such as gestational diabetes, which increases women's risk of later developing type II diabetes.[11,18,19] Smoking during pregnancy is a teratogen that increases the risk of offspring being born with low birth weight.[20]

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Assessing engagement in these health behaviors is critical as they represent a spectrum of lifestyle factors that impact maternal and foetal health during pregnancy, and also later in life.

Although the importance of health behaviors during pregnancy has been acknowledged by various professional organizations, the proportion of US women who engage in several recommended health behaviors is not clear. Previous studies have focused on a specific behavior or two (i.e. smoking and/or diet).[21–23] Given that multiple health behaviors have been associated with pregnancy and offspring outcomes, a comprehensive understanding of which health behaviors US pregnant women engage in, and the characteristics associated with lack of engagement are important for public health interventions. The objective of this study was to examine engagement in five recommended health behaviors (adequate fruit and vegetable consumption, prenatal multivitamin use, adequate physical activity, adequate sleep and abstention from smoking) among a nationally representative sample of pregnant women in the US, and to identify the characteristics associated with engaging in these health behaviors using data from the National Health and Nutrition Examination Survey (NHANES) 2007–2014.

Methods

Data source and study population

The current study included pregnant women between the ages of 20–44 years who participated in the NHANES 2007–2014 cycles. The design and procedures of NHANES have been detailed on the Center for Disease Control and Prevention (CDC) website. Briefly, the NHANES is a nationally representative cross-sectional survey of US non-institutionalized civilians that uses a complex multistage probability sampling method and includes a household interview and physical examination. The procedures and protocols of NHANES 2007–2014 were approved by the institutional review board of the CDC/National Center for Health Statistics. This secondary analysis of NHANES data was not subject to further institutional review.

Pregnancy status and demographic information

Pregnancy status was ascertained through either self-report during the household interview, or via a urine pregnancy test during the physical exam. Participants' age, race/ethnicity, education, household income, and marital status were collected during the interview.

Health behavior recommendations

We examined the following five health behaviors captured by the NHANES: (i) fruit and vegetable consumption, (ii) prenatal multivitamin use, (iii) physical activity, (iv) sleep duration and (v) abstention from smoking. Dietary intake was assessed by two 24-h dietary recalls administered by trained interviewers. Participant's daily intake of fruits and vegetables was calculated by taking the average of the two 24-h dietary recalls. The food groups were categorized using the US Department of Agriculture (USDA) Food and Nutrient Database for Dietary Studies 2.0. Duration and quantity of prenatal multivitamins were assessed among participants who reported taking any prescription or non-prescription supplements in the past 30 days. The folic acid, vitamin D (D2 + D3), calcium and iron content of the prenatal multivitamins was assessed by linking the NHANES dietary supplement file to the supplement database, which contains detailed information on the supplement ingredients. The quantity of these vitamins and minerals were assessed as the American College of Obstetricians and Gynecologists (ACOG) provides specific recommended daily allowances for women during pregnancy.[24] Physical activity was assessed by the frequency, duration and exertion level of physical activity for work, transportation and leisure activities that participants typically engaged in during a week. In the NHANES, vigorous physical activity is assigned a Metabolic Equivalent Task (MET) score of 8 and moderate physical activity is assigned a MET score of 4.[25] Hours of sleep per night was based on participants' response to 'how much sleep do you usually get at night on weekdays/workdays?'. Smoking status was based on response to three questions, 'never having smoked 100 cigarettes', or 'currently not smoking at all' and 'how long since quit smoking'.

Statistical analysis

Engagement in each behavior was dichotomized based on meeting recommendations for individual health behaviors at the sampled time points during pregnancy. Not smoking during pregnancy was categorized as never having smoked or not smoking during pregnancy, by comparing the time since quitting smoking to participant's gestational age (GA). Women who reported consuming five servings (400 g) of fruits or vegetables per day were categorized as achieving adequate fruit and vegetable consumption.[26,27] All women who reported taking prenatal multivitamins in the past 30 days were categorized as engaging to prenatal multivitamin use.[24] In a subsample of women who reported taking supplements and had data on GA of pregnancy ($n = 90$), we further examined the duration of use during pregnancy. Women who

engaged in physical activities with a MET ≥ 4 for at least 150 min per week[28] were categorized as achieving adequate physical activity. Women who reported receiving seven or more hours of sleep per night[26] were categorized as achieving adequate sleep.

Descriptive results are presented as a weighted percent for categorical variables and weighted mean (standard error) for continuous variables. Differences in characteristics among pregnant women were tested with chi-squared tests with robust variance estimates. Statistical analysis focused on estimating the cumulative number (0–5) of recommended health behaviors women engaged in and the proportion of women who met each individual health behavior at the sampled time in pregnancy.

For the recommendation that women engaged in the least, multivariable logistic regression models were used to estimate the odds ratios (OR) and 95% confidence intervals (95% CI) for the associations between women's characteristics and the health behavior. We examined age, race, education, annual household income and marital status. All analyses were conducted using SAS, version 9.3 (SAS Institute, Cary, NC) with tests of significance (two-sided) at the level of 0.05.

Results

A total of 248 women were included in the current study and their characteristics are presented in Table 1. The mean (standard error) age was 28.78 (0.42) years. The racial/ethnic background of the sample was 48.86% of non-Hispanic whites, 18.11% of non-Hispanic black, 20.73% of Hispanic and 12.29% other race/ethnicity. Most women (65.05%) reported having at least some college education, 77.18% were married or living with a partner, and 20.41% reported an annual household income less than $20 000. Of the 138 women who reported their GA, the median GA was 5.12 (interquartile range [IQR]: 2.60, 6.70) months.

The percentage of women who engaged in a cumulative number of health behaviors are presented in Figure 1. Very few women engaged in zero, one, or all five recommendations (0.74%, 5.29% and 10.17% respectively). The mean number of cumulative health behaviors women engaged in was three.

The proportion of women who met recommendations for each health behavior at the sampled time in pregnancy is shown in Table 2. Overall, 87.40% of pregnant women met recommendations for not smoking, followed by engaging in adequate physical activity (73.04%), adequate sleep (71.81%), taking prenatal multivitamins (61.62%), and consuming

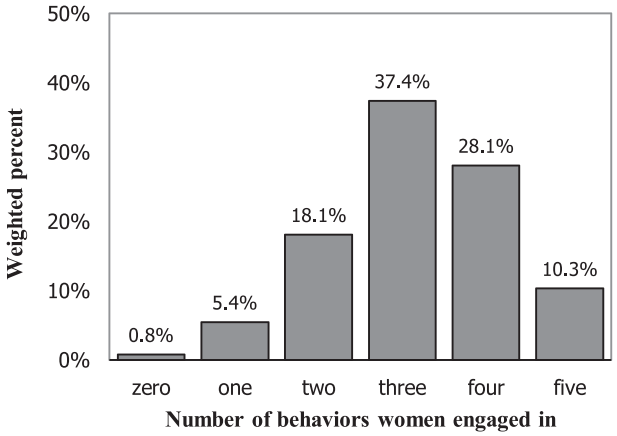

Fig. 1 Percentage of women engaging in a cumulative number of health behaviors. Percentage of women engaging in health behaviors during pregnancy, National Health and Nutrition Examination Survey 2007–2014. Mean number of behaviors women engaged in was three. Definitions of the behavior recommendations can be found in Table 2. Data are presented as weighted percent and unweighted frequency. For data on prenatal supplements, and adequate fruit or vegetable consumption estimates may not represent engagement in these health behaviors continuously throughout pregnancy.

Table 1 Characteristics of pregnant women ($N = 248$)

Characteristics, % (N)	*All*	*P*
Age, years	28.780 (0.42)§	
20–24	35.17 (97)	<0.0001
25–35	47.27 (111)	
>35	17.56 (40)	
Race/ethnicity		<0.0001
Non-Hispanic white	48.86 (73)	
Non-Hispanic black	18.11 (64)	
Hispanic	20.73 (78)	
Other*	12.29 (33)	
Annual household income		0.10
<$20 000	20.41 (61)	
$20 000–$44 999	23.95 (69)	
$45 000–$74 999	22.25 (42)	
≥$75 000	33.39 (52)	
Education		<0.0001
≤11th grade	17.32 (59)	
High school graduate	17.62 (51)	
≥Some college	65.05 (138)	
Marital status		<0.0001
Single	20.20 (62)	
Married or living w. partner	77.18 (175)	
Widowed/divorced/separated	2.63 (10)	

Data are presented as weighted percent and unweighted frequency. Weighted results to account for the complex survey design.

§weighted mean and standard error.

*Other includes multiracial.

TABLE 2 Proportion of women who engaged in health behaviors ($N = 248$)

Health behavior	*Percentage*	*P*
Adequate fruit/vegetable consumption	35.42	<0.001
Use of prenatal vitamins	61.62	0.001
Adequate physical active[§]	73.04	<0.001
Adequate sleep	71.81	<0.001
Non-smoking	87.14	<0.001

Data are presented as weighted percent and unweighted frequency. Weighted results to account for complex survey design. Chi-Squared tests for significance were based on robust variance estimates and compare the proportion of women who met each health behavior to women who did not. For data on prenatal supplements, and adequate fruit or vegetable consumption estimates may not represent engagement in these health behaviors continuously throughout pregnancy. Engagement in health behavior defined as: Sleep ≥ 7 h/day; Physical activity ≥ 150 min/week of moderate-intensity activity; Fruit/Vegetable ≥ 5 servings (400 g) per day.

[§]Only 172 women reported data on physical activity.

adequate fruits and vegetables (35.42%). Of the women who did not meet recommendations for fruit and vegetable ($n = 147$) consumption, 41.78% ($n = 73$) were also not taking prenatal multivitamins. In the previous 30 days, the median number of days women reported taking one prenatal multi-vitamin was 28.44 (19.07, 29.22) days. The means of the prenatal multi-vitamin ingredients were: folic acid 730.58 (15.73) mg; vitamin D 8.60 (0.23) mcg; calcium 195.26 (3.90) mg; and iron 27.28 (0.84) mg. In a sub-sample of women who reported taking prenatal multivitamins and had data on GA of pregnancy ($n = 90$), the difference between duration of supplement use and GA was 31.5 (0.53, 61.82) days (days of prenatal multivitamin use subtracted from GA), and 24.55% ($n = 23$) of women took prenatal multivitamins prior to conception (days of prenatal multivitamin use > GA). Among women who reported their current trimester of pregnancy ($n = 138$), the following percentages reported taking prenatal multivitamins: 24.39% in their 1st, 83.33% in their 2nd, and 81.63% in their 3rd trimester.

In multivariable analysis (Table 3), Hispanic women (OR = 3.69; 95% CI, 1.47, 9.25) and women of 'other' race (OR = 3.36; 95% CI, 1.17, 9.66) were more likely to consume adequate fruits and vegetables compared to non-Hispanic white women. Women who were high school graduates were less likely to consume adequate fruits and vegetables compared to women who had at least some college education (OR = 0.46; 95% CI, 0.22, 0.97). None of the sociodemographic characteristics were associated with engaging in more than three recommendations (Supplementary Table I).

Discussion

Main findings of this study

To our best knowledge, this study was the first to examine engagement in five health behavior recommendations for pregnant women in a nationally representative US sample, and we found that only 10% of women engaged in all five health behaviors. Our results showed that the majority of pregnant women in the USA do not consume the recommended amount of fruits and vegetables (five servings per day).[26,27] Compared with non-Hispanic white women, Hispanic women or women of 'other' race were 3.69 and 3.36 times more likely to consume recommended amounts of fruits and vegetables. More than 70% of women met recommendations for adequate physical activity, sleep, or abstention from smoking.

What is already known on this topic

The prevalence of smoking during pregnancy in the USA has been decreasing since 2000.[29] In a recent 2014 study using birth certificate data, only 8.4% of women reported smoking at any time during pregnancy,[30] which is similar to the percentage of pregnant women who reported smoking in the current analysis.

Adequate maternal nutrient intake during pregnancy is essential for fetal development. As such, healthy dietary intakes with proper supplementation have been recommended by several organizations (e.g. ACOG, the World Health Organization, the US Department of Health and Human Services). Despite these recommendations, women have reported not taking supplements because of nausea and vomiting.[31] In a recent analysis of supplement use among pregnant women using NHANES 1999–2006 data, 78% of pregnant women reported taking any supplements in the previous 30 days with 55–60% of women in their first trimester taking a folic acid- or iron-containing supplement versus 76–78% in their 2nd trimester and 89% in their third trimester.[32] In the current study, we specifically examined the percentage of pregnant women taking prenatal multivitamins. We found that a lower percentage of pregnant women reported taking prenatal multivitamins in the previous 30 days (61.62%) and in their 1st trimester (24.39%), with comparable results to previous studies among women in their 2nd (83.33%) and 3rd trimester (81.63). In the current study, the lower percentage of women in their 1st trimester who reported taking prenatal multivitamins is likely due to our analysis of prenatal multivitamins versus the previous study that examined the use of any supplement containing folic acid or iron. Overall, the prenatal multivitamins consumed by women in the current study met the recommendations by

TABLE 3 Women's characteristics associated with adequate fruit/vegetable intake

	Descriptive analysis for adherence		*Multivariable model for adherence*	*P*
	Yes	*No*	*OR (95% CI)*	
Characteristics, % (*N*)	35.42 (88)	64.58 (147)		
Age, years[§]	29.38 (0.69)	28.37 (0.48)	1.03 (0.97, 1.09)	0.40
Race/ethnicity				
Non-Hispanic white	37.82 (19)	56.16 (51)	1.00	
Non-Hispanic black	14.72 (18)	18.93 (41)	1.39 (0.51, 3.80)	0.52
Hispanic	26.44 (35)	16.72 (39)	3.69 (1.47, 9.25)	0.01
Other*	21.02 (16)	8.19 (16)	3.36 (1.17, 9.66)	0.03
Annual household income				
<$20 000	16.82 (18)	20.65 (37)	0.53 (0.17, 1.68)	0.27
$20 000–$44 999	23.03 (24)	24.10 (42)	0.69 (0.21, 2.32)	0.54
$45 000–$74 999	25.88 (17)	21.88 (25)	1.01 (0.31, 3.23)	0.99
≥$75 000	34.27 (19)	33.37 (31)	1.00	
Education				
≤11th grade	18.37 (23)	17.09 (33)	0.95 (0.40, 2.26)	0.90
High school graduate	11.47 (15)	21.89 (35)	0.46 (0.22, 0.97)	0.04
≥Some college	70.16 (50)	61.02 (79)	1.00	
Marital status				
Single	19.69 (18)	19.72 (40)	1.40 (0.56, 3.50)	0.46
Married or living w. partner	77.28 (66)	77.67 (100)	1.00	
Widowed/divorced/separated	3.03 (4)	2.62 (6)	1.03 (0.97, 1.09)	0.79

Data are presented as weighted percent and unweighted frequency.

[§]Weighted mean and standard error. Weighted results to account for complex survey design. Significant differences among descriptive statistics based on *P* value derived from chi-squared and *t*-tests and used robust variance estimates to compares the proportion of women who consumed adequate fruits/vegetables to women who did not.

*Other includes multiracial. The multivariable model indicates the OR adequate to fruit/vegetable intake for each characteristic while holding the others constant. Data on adequate fruit or vegetable consumption estimates may not represent engagement in these health behaviors continuously throughout pregnancy.

ACOG for folic acid, vitamin D, calcium and iron. However dietary or other sources of vitamin D and calcium would be needed for women to fully achieve all the recommended levels.

We are not aware of other studies that reported the percentage of US pregnant women who adhered to the fruit and vegetable intake recommendation using nationally representative data. A recent CDC study reported that only 15.1% of US women met fruit recommendations of 1.5–2.0 cups per day, and 10.9% met vegetable recommendations of 2–3 cups per day using the Behavioral Risk Factor Surveillance System (BRFSS) 2015 data.[33] Differences in population, sampling methods, and data collection should be considered when comparing our results to findings from the CDC. The CDC study included women aged ≥18 years, while our study only included pregnant women. The sampling methods between our study which uses the NHANES data and the BRFSS are different. The BRFSS is an annual, state-based, random-digit-dialed telephone household survey. Lastly, unlike NHANES that uses a 24-h dietary recalls, the BRFSS phone-based survey only asks six questions to assess how many times per day, week, or month the participants consumed (i) 100% fruit juice, (ii) whole fruit, (iii) dried beans, (iv) dark green vegetables, (v) orange vegetables and (vi) other vegetables, during the previous month. Daily frequency of intake is calculated by dividing reported intake by 7 for intake reported by week, and by 30 for intake reported by month. Despite the higher percentage in the current study than what has been previously reported, roughly two-thirds of women were not meeting recommendations. Our finding that a small portion of women adhered to fruit and vegetable recommendations is particularly critical given that higher consumption of fruits and vegetables has been associated with a reduced risk of pregnancy complications, such as gestational diabetes.[34] Studies of adult dietary patterns have identified availability, access, preparation time and cost

as reasons adults report not eating adequate fruits and vegetables.[35,36]

Independent of annual household income, we found that Hispanic or women of 'other' race were more likely to meet fruit and vegetable recommendations than non-Hispanic white women, which may suggest that cultural differences rather than cost explain differences in meal preferences. Our results are consistent with a recent study among women enrolled in the Special Supplemental Nutrition Program for Women, Infants, and Children (a USDA Food and Nutrition Service assistance program for low-income pregnant or breastfeeding women, and young children[37]). In this study, Hispanic women consumed a higher intake of fruit, dark green, and 'other' vegetables compared to non-Hispanic white women.[38] Although the current study did not examine particular consumption patterns relative to known diets (e.g. Mediterranean or DASH—Dietary Approaches to Stop Hypertension), it may be that non-Hispanic white women tend to consume a Western-style diet—low in fruits and vegetables, high in saturated and trans fats, processed meat, sugar and salt. Our finding that higher education was associated with adequate fruit and vegetable consumption is in line with previous studies that report educational achievement being positively associated with a higher quality diet among pregnant women.[16,23]

What this study adds

Pregnancy has been viewed as a 'window of opportunity' for women to modify their lifestyle during pregnancy and maintain healthy behaviors postpartum.[39] Diet and environmental exposures during pregnancy can have long-lasting health impacts on both mother and offspring. Our finding that a low percentage of women consumed recommended amounts of fruits and vegetables, and that approximately half of women did not take prenatal multivitamins, highlights a critical gap in women's prenatal health in the US. Inadequate dietary intake during pregnancy is of particular public health concern since altering women's diet is a modifiable factor with the potential to have a substantial health impact.[16,40–42] Considering that the majority of pregnant women in the USA are non-Hispanic white, our findings suggest that increased attention to racial/ethnic differences in diet during the prenatal period is needed to ensure women are either meeting diet recommendations or taking supplements to account for lack of nutrients from dietary sources.

Limitations of this study

The NHANES is designed to assess the health and nutritional status of adults and children in the USA, but due to its cross-sectional design, we cannot examine whether engagement in the five health behaviors was carried out consistently throughout pregnancy. The current study used data from two 24-h dietary recalls to assess fruit and vegetable intake, which is dependent on memory and ability to summarize food and drinks consumed the day prior. However, this method is considered the best dietary assessment to estimate the average dietary consumption in large populations.[43] The 24-h dietary recall is administered by trained research staff and includes multiple prompts to reduce the likelihood of missing food or drinks consumed by the participants. This dietary assessment method has also been commonly accepted for measuring dietary intake among pregnant women.[44,45] We were not able to examine trimester-specific health behaviors due to substantial missing data for GA. Women who are further along in their pregnancy may be more likely to engage in healthy behaviors, either because they have received more information from prenatal care visits, or because they have had more time to implement lifestyle adjustments. In addition, we were not able to determine if all participants had taken prenatal multivitamins throughout pregnancy due to the cross-sectional design and the missing GA data. However, among a subgroup of women with information on both length of prenatal multivitamin use and GA, there was only an average of a 1-month difference between GA and the length of time taking prenatal multivitamins.

Despite these limitations, this study examined the most up-to-date data on a variety of health behavior recommendations during pregnancy in a nationally representative sample of US women. Future studies with more complete data and from longitudinal designs are warranted to explore if engagement in health behaviors differ by GA or are sustained throughout pregnancy.

Supplementary data

Supplementary data are available at the *Journal of Public Health* online.

Conflict of interest

The authors declare that they have no conflict of interest.

References

1 Fowden AL, Giussani DA, Forhead AJ. Intrauterine programming of physiological systems: causes and consequences. *Physiology* 2006;**21**(**1**):29.

2 McMillen IC, Robinson JS. Developmental origins of the metabolic syndrome: prediction, plasticity, and programming. *Physiol Rev* 2005;**85**(**2**):571–633.

3 Barker DJP, Eriksson JG, Forsén T *et al.* Fetal origins of adult disease: strength of effects and biological basis. *International journal of epidemiology* 2002;**31**(**6**):1235–9.

4 Teh AL, Pan H, Chen L *et al.* The effect of genotype and in utero environment on interindividual variation in neonate DNA methylomes. *Genome Res* 2014;**24**(**7**):1064–74.

5 Hui L, Bianchi DW. Recent advances in the prenatal interrogation of the human fetal genome. *Trends Genet: TIG* 2013;**29**(**2**):84–91.

6 Center for Disease Control, *Morbidity and mortality weekly report: Recommendations to Improve Preconception Health and Health Care - United States: A Report of the CDC/ATSDR Preconception Care Work Group and the Select Panel on Preconception Care*., in Reports and, K. Johnson, et al., (ed). 2006: Atlanta, GA: U.S. Dept. of Health, Education, and Welfare, Public Health Service, Center for Disease Control. **55**(RR06); 1–23.

7 American College of Obstetricians and Gynecologists. *Patient Education Frequently Asked Questions*. 2017 [cited 2018 May 16th]; Available from: https://www.acog.org/Patients/Patient-Education-FAQs-List.

8 Walsh RA. Effects of maternal smoking on adverse pregnancy outcomes: examination of the criteria of causation. *Human Biol* 1994;**66**(**6**):1059–92.

9 Villamor E, Rifas-Shiman SL, Gillman MW *et al.* Maternal intake of methyl-donor nutrients and child cognition at 3 years of age. *Paediatr Perinat Epidemiol* 2012;**26**(**4**):328–35.

10 Hirshkowitz M, Whiton K, Albert SM *et al.* National Sleep Foundation’s updated sleep duration recommendations: final report. *Sleep Health: J Natl Sleep Foundation* **1**(**4**):233–43.

11 Rawal S, Hinkle SL, Zhu Y *et al.* A longitudinal study of sleep duration in pregnancy and subsequent risk of gestational diabetes: findings from a prospective, multiracial cohort. *Am J Obstetr Gynecol* 2016;**216**(**4**):399.

12 Abu-Saad K, Fraser D. Maternal nutrition and birth outcomes. *Epidemiol Rev* 2010;**32**:5–25.

13 Norris T, FP MC, Khashan AS *et al.* Do changing levels of maternal exercise during pregnancy affect neonatal adiposity? Secondary analysis of the babies after SCOPE: evaluating the longitudinal impact using neurological and nutritional endpoints (BASELINE) birth cohort (Cork, Ireland). *BMJ Open* 2017;**7**(**11**):e017987.

14 Gluckman PD, Hanson MA. The developmental origins of health and disease. In: Wintour EM, Owens JA (eds). *Early Life Origins of Health and Disease*. Boston, MA: Springer US, 2006, 1–7.

15 Knudsen VK, Orozova-Bekkevold IM, Mikkelsen TB *et al.* Major dietary patterns in pregnancy and fetal growth. *Eur J Clin Nutr* 2007;**62**:463–70.

16 Mikkelsen TB, Osler M, Orozova-Bekkevold I *et al.* Association between fruit and vegetable consumption and birth weight: a prospective study among 43,585 Danish women. *Scand J Public Health* 2006;**34**(**6**):616–22.

17 ACOG Committee on Obstetric Practice. ACOG Committee opinion no. 762 summary: Prepregnancy Counseling. *Obstet Gynecol* 2019;**133**(**1**):228–30.

18 Mijatovic-Vukas J, Capling L, Cheng S *et al.* Associations of diet and physical activity with risk for gestational diabetes mellitus: a systematic review and meta-analysis. *Nutrients* 2018;**10**(**6**):e698.

19 Zhu YY, Zhang CL. Prevalence of gestational diabetes and risk of progression to type 2 diabetes: a global perspective. *Curr Diabetes Rep* 2016;**16**(**1**):

20 Kramer MS. Intrauterine growth and gestational duration determinants. *Pediatrics* 1987;**80**:

21 Simmons D, Jelsma JG, Galjaard S *et al.* Results from a European multicenter randomized trial of physical activity and/or healthy eating to reduce the risk of gestational diabetes mellitus: the DALI lifestyle pilot. *Diabetes Care* 2015;**38**(**9**):1650–6.

22 Badon SE, Enquobahrie DA, Wartko PD *et al.* Healthy lifestyle during early pregnancy and risk of gestational diabetes mellitus. *Am J Epidemiol* 2017;**186**(**3**):326–33.

23 Crozier SR, Robinson SM, Borland SE *et al.* Do women change their health behaviours in pregnancy? Findings from the Southampton Women's Survey. *Paediatr Perinat Epidemiol* 2009;**23**(**5**): 446–53.

24 American College of Obstetricians and Gynecologists. Nutrition during pregnancy. 2018 [cited 2018 May 16th]; Available from: https://www.acog.org/Patients/FAQs/Nutrition-During-Pregnancy.

25 Centers for Disease Control. *National Center for Health Statistics (NCHS). National Health and Nutrition Examination Survey Questionnaire (or Examination Protocol, or Laboratory Protocol). 2007–2014*. MD: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention: Hyattsville.

26 U.S Department of Health and Human Services and U. S Department of Agriculture, Dietary Guidelines for Americans 2015-2020. 8th ed. 2015.

27 World Health Organization and Food and Agriculture Organization. *Diet, Nutrition and the Prevention of Chronic Diseases* Who Technical Report Series. Geneva, Switzerland: World Health Organization, 2002.

28 Kader M, Naim-Shuchana S. Physical activity and exercise during pregnancy. *Eur J Physiother* 2014;**16**(**1**):2.

29 Tong VT, Jones JR, Dietz PM *et al.* Trends in smoking before, during, and after pregnancy - pregnancy risk assessment monitoring system (PRAMS), United States, 31 sites, 2000-2005. *MMWR Surveill Summ* 2009;**58**(**4**):1–29.

30 Curtin SC, Matthews TJ. Smoking prevalence and cessation before and during pregnancy: data from the birth certificate, 2014. *Natl Vital Stat Rep* 2016;**65**(**1**):1–14.

31 Nguyen P, Thomas M, Koren G. Predictors of prenatal multivitamin adherence in pregnant women. *J Clin Pharmacol* 2009;**49**(**6**):735–42.

32 Branum AM, Bailey R, Singer BJ. Dietary supplement use and folate status during pregnancy in the United States. *J Nutr* 2013;**143**(**4**):486–92.

33 Lee-Kwan S, Moore LV, Blanck HM *et al.* Disparities in state-specific adult fruit and vegetable consumption - United States, 2017. *MMWR Morb Mortal Wkly Rep* 2015;**66**(**45**):1241–7.

34 Zhang C, Schulze MB, Solomon CG *et al.* A prospective study of dietary patterns, meat intake and the risk of gestational diabetes mellitus. *Diabetologia* 2006;**49**(**11**):2604–13.

35 Pollard J, Kirk SF, Cade JE. Factors affecting food choice in relation to fruit and vegetable intake: a review. *Nutr Res Rev* 2002;**15**(**2**): 373–87.

36 Yeh MC, Ickes SB, Lowenstein LM *et al.* Understanding barriers and facilitators of fruit and vegetable consumption among a diverse multi-ethnic population in the USA. *Health Promot Int* 2008;**23**(**1**):42–51.

37 United States Department of Agriculture Food and Nutrition Service. Women, Infants, and Children (WIC). 2018 [cited 25th May 2018]; Available from: https://www.fns.usda.gov/wic/women-infants-and-children-wic.

38 Di Noia J, Monica D, Cullen KW *et al.* Differences in fruit and vegetable intake by race/ethnicity and by Hispanic origin and nativity among women in the special supplemental nutrition program for women, infants, and children, 2015. *Prev Chronic Dis* 2016;**13**:E115.

39 Olander EK, Smith DM, Darwin Z. Health behaviour and pregnancy: a time for change. *J Reprod Infant Psychol* 2018;**36**(**1**):1–3.

40 Painter RC, de Rooij SR, Bossuyt PM *et al.* Early onset of coronary artery disease after prenatal exposure to the Dutch famine. *Am J Clin Nutr* 2006;**84**(**2**):322–7 quiz 466-7.

41 Godfrey K, Robinson S, Barker DJ *et al.* Maternal nutrition in early and late pregnancy in relation to placental and fetal growth. *BMJ* 1996;**312**(**7028**):410–4.

42 Zhang C, Liu S, Solomon CG *et al.* Dietary fiber intake, dietary glycemic load, and the risk for gestational diabetes mellitus. *Diabetes Care* 2006;**29**(**10**):2223–30.

43 Baranowski, T., 24-Hour recall and diet record methods, in *Nutritional Epidemiology*, W.C. Willett, (ed). 2012, Oxford University Press. p. **63–83**.

44 Shin D, Lee KW, Song WO. Dietary patterns during pregnancy are associated with risk of gestational diabetes mellitus. *Nutrients* 2015;**7**(**11**):9369–82.

45 Cioffi CE, Figueroa J, Welsh JA. Added sugar intake among pregnant women in the United States: National Health and nutrition examination survey 2003-2012. *J Acad Nutr Diet* 2018;**118**(**5**): 886–895.e1.